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Performance evaluation of reaction and impulse turbines using ANN, ANFIS, and ANN-PSO models in MATLAB

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ABSTRACT

Turbomachines are categorized as either reaction or impulse machines based on the proportion of dynamic and static heads involved in energy transfer. Reaction turbines are characterized by the passage of the working gas through a set of stationary blades, referred to as stator blades. These stator blades serve to control the fluid's movement and enhance its velocity. On the other hand, impulse turbines feature a set of fixed nozzles through which the working fluid flows. These nozzles convert the pressure energy of the working medium into kinetic energy. Reaction turbines operate at high temperatures and pressures, constituting oil-free exhaust systems. They are typically employed in applications where such conditions are essential. Impulse turbines, on the other hand, are designed for extracting energy from swiftly moving fluids, making them particularly well-suited for hydroelectric power generation. Both reaction and impulse turbines have undergone extensive experimental research. A dataset comprising one hundred and ninety-seven (197) data points was generated from these turbine machines. Of these, one hundred and twenty (120) were derived from reaction turbines, while seventy-seven (77) were obtained from impulse turbines. The datasets were employed to develop models using ANN, ANFIS, and ANN-PSO within the MATLAB environment. For the reaction turbine, the ANN-PSO model achieved the highest regression test value (R^2) of 0.9972. On the other hand, for the impulse turbine, the ANN model attained the highest regression value, with an R^2 of 0.99973.

KEYWORDS

Turbines; Artificial Neural Network; Particle swarm optimization; Adaptive neuro-fuzzy inference system

ARTICLE HISTORY

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Introduction

Turbines are machines designed to generate shaft power and torque by harnessing a momentum shift within the working medium that passes through them [1]. This medium can be in the form of vapor, gas, or liquid. To achieve the necessary high velocity for meaningful momentum changes, substantial pressure disparities between the turbine's exhaust and inlet are essential [1]. Pressurized gas sources can include previously compressed (and possibly heated) gas, as in a gas turbine, or in the turbine of a turbocharged internal combustion engine (IC). In power plants, nuclear fuels or fossil fuels are employed to heat large quantities of water into high-pressure steam vapor.

A turbine then converts the energy of the steam into mechanical work, driving electric generators [1]. This crucial process provides the electrical power used in our homes and businesses. Impulse turbines utilize buckets on the runner to harness the kinetic energy of a water stream [2]. After striking the buckets and driving the runner, the working medium exits the turbine housing. Impulse turbines are particularly well-suited for sites with high head and low flow rates. Turgo, Pelton, and cross-flow turbines represent different types of impulse turbines [2]. Specifically, Pelton turbines excel in locations with high water drops and low flow rates [2]. These turbines feature a circular disk affixed to the shaft, which is linked to the generator's rotor. Buckets are arranged around the circumference of the disk, such that when the working fluid impacts the buckets, they move along the tangent of the disk, as illustrated in Figure. 1. The efficiency of the Pelton turbine is capped at 90% due to nozzle losses, frictional losses, and aerodynamic drag. As the load on the turbine fluctuates, so does its speed, thereby affecting the frequency of electricity generation [2]. To maintain the turbine's speed and frequency, the flow rate through the turbine is regulated by a valve positioned on the jet [3].

Figure 1. Schematic representation of a Pelton turbine [3].

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